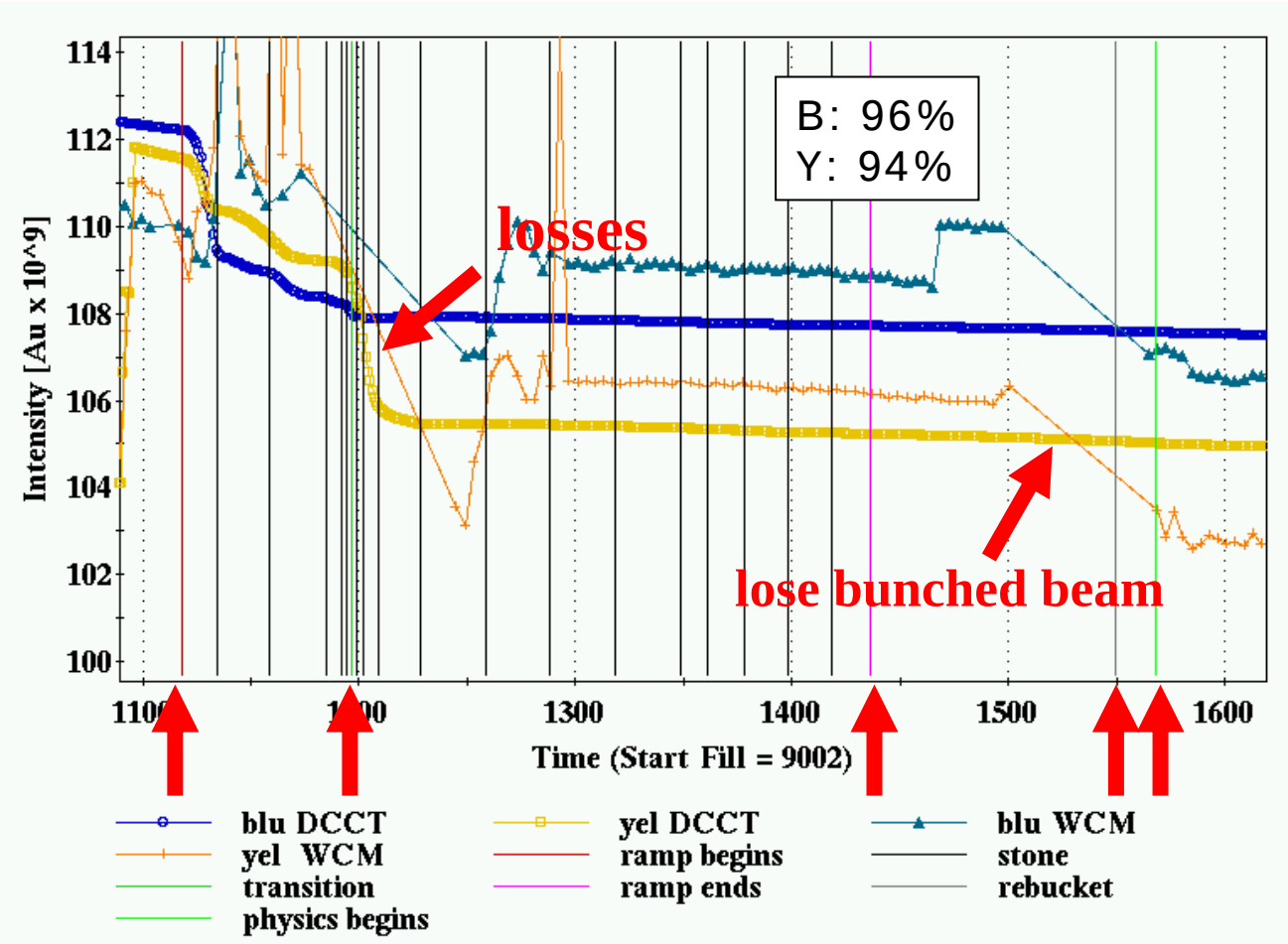
RHIC Machine Performance in Run 7

- Introduction: a ramp
- Expectations and goals for Run 7
- Overview of Machine Performance
  - machine setup
  - machine ramp up
  - physics operation
- Conclusions

Introduction:
A "typical" ramp with Au-Au



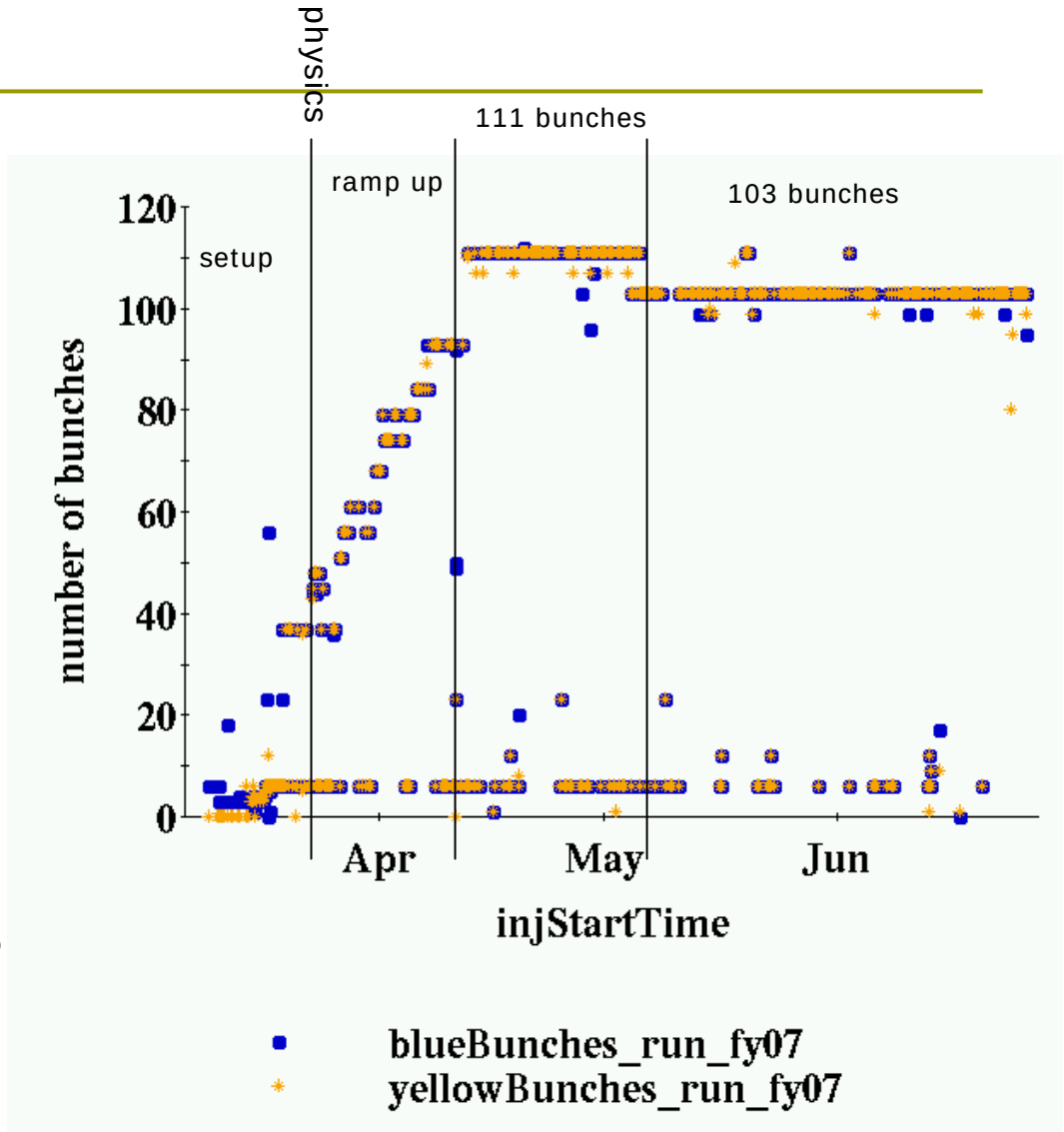
- Typically some early losses
- Most losses around transition (intensity dependend)
- Some losses of bunched beam with rebucketing
- Physics begins after rebucketing
- **Transmission efficiency is crucial for performance!**

Expectations and Goals for Run-7

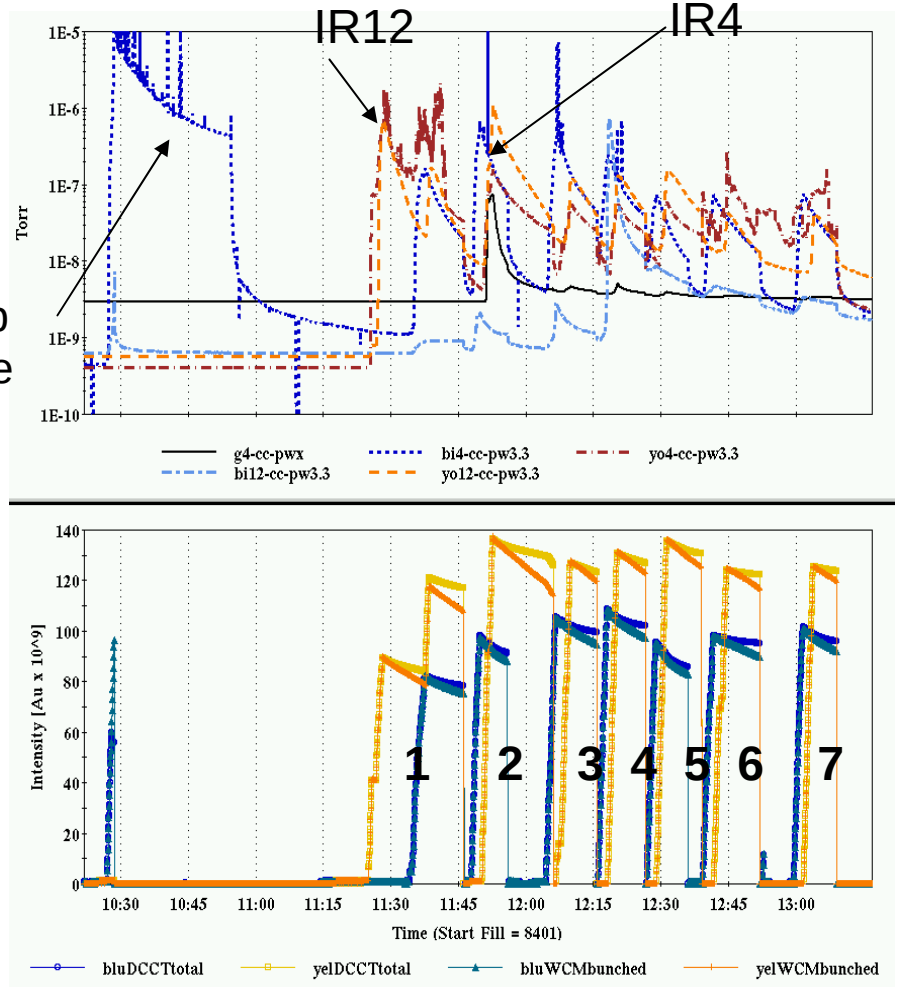
- Do better than Run-4
- Increase number of bunches to 111
- Reach 60% time at store on average
- Reach avg. luminosity/store
  - > 8 10^{26} cm-2 s-1 routinely
- Reach peak luminosity/store
  - > 30 10^{26} cm-1 s-1
- Increase bunch intensity

Machine Setup: maximize number of bunches

- Total setup time was 5 weeks
- Only 2 weeks from both rings being cold
- 2 weeks lost on cryo problem
- Only 4 days to reach 90% ramp efficiency
- Reached 111 (max. possible number!) bunches after 2 weeks of physics operation
- Physics declared Mar 26th with 51 bunches and $L_{peak} = 14\ 10^{26}\ s^{-1}cm^{-2}$
- Already higher performance than last week of Run-4 with 45 bunches and $L_{peak} = 11\ 10^{26}\ cm^{-2}\ s^{-1}$!

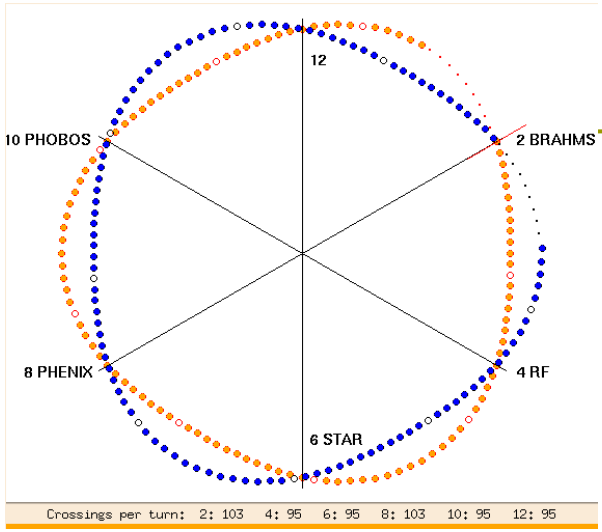


Scrubbing at the beginning of the run to reach higher bunch numbers

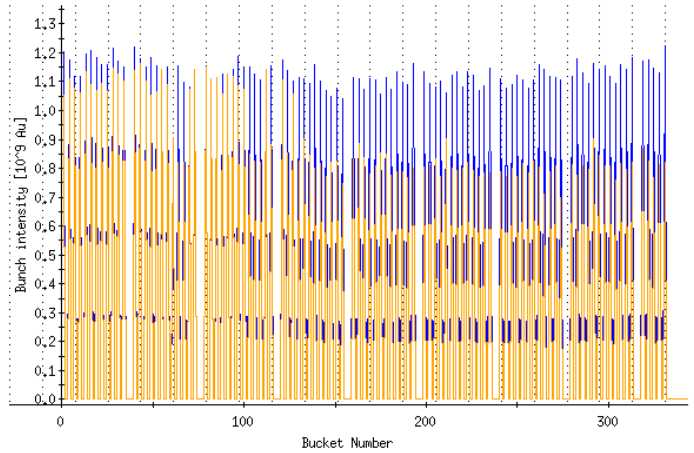


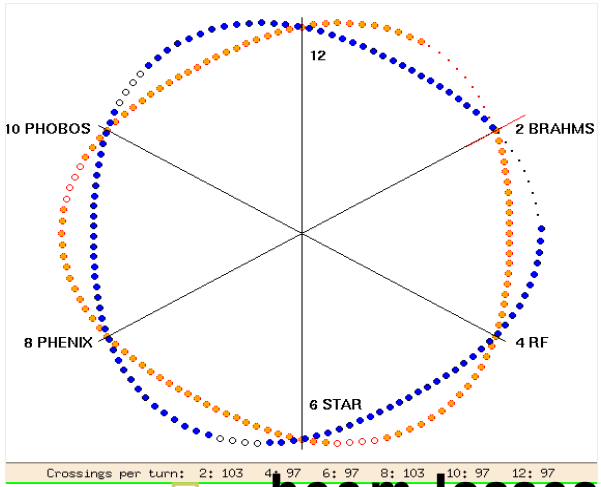
- Before we could go for higher bunch numbers:
  - Pressure bump moves from IR12 to IR4
  - Pressure bump reduces after 4th high intensity injection
  - Spend a total of 2 hours

Total Bunch Number reduced to 103: why?

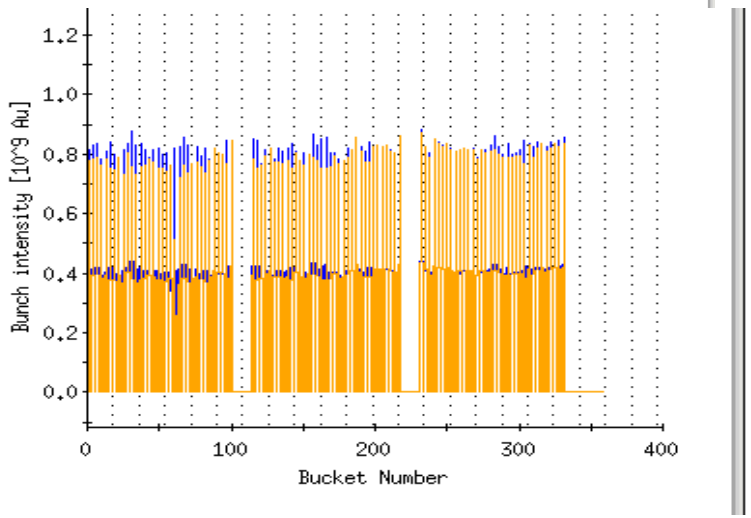


standard



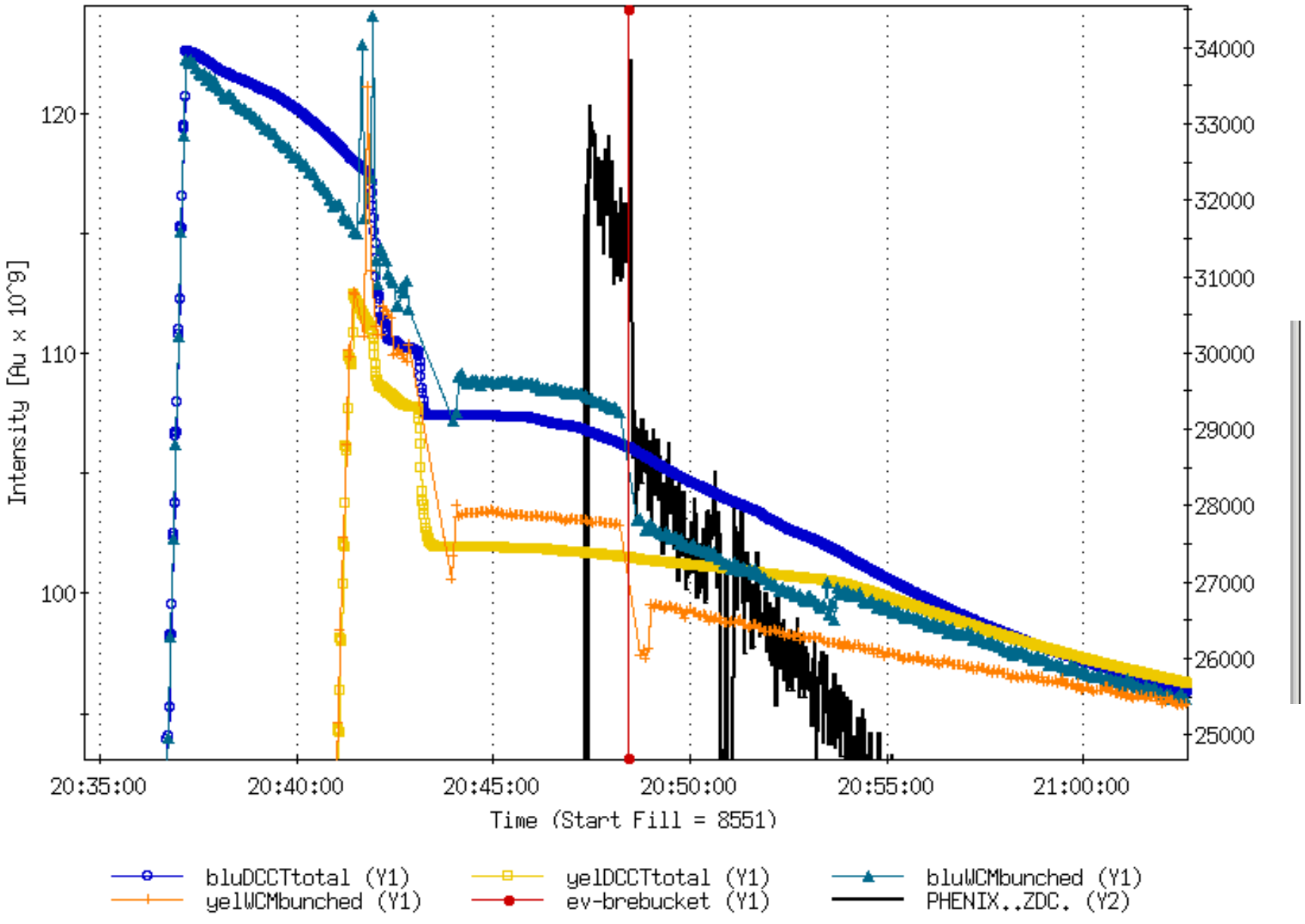


Fancy Gap:
More crossings:
95->97



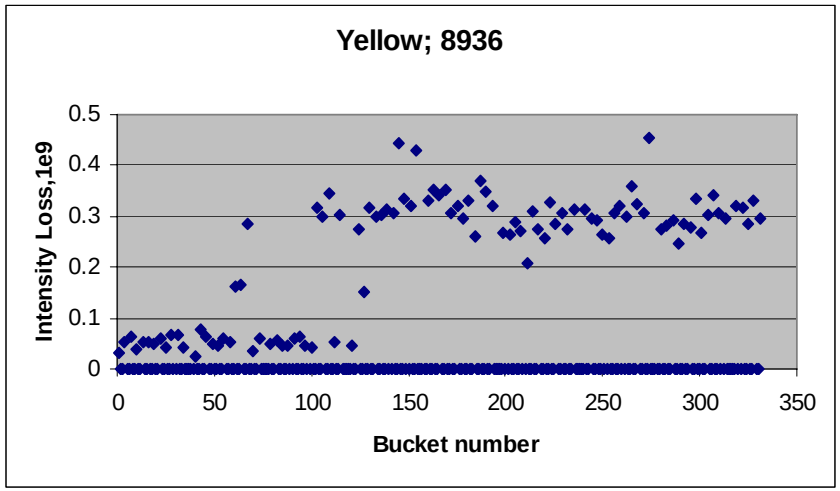
- beam losses along the bunch train (next slide)
- Rebucketing issues: debunching beam
- Could we go to higher intensity / bunch?

Total Bunch Number reduced to 103: why?

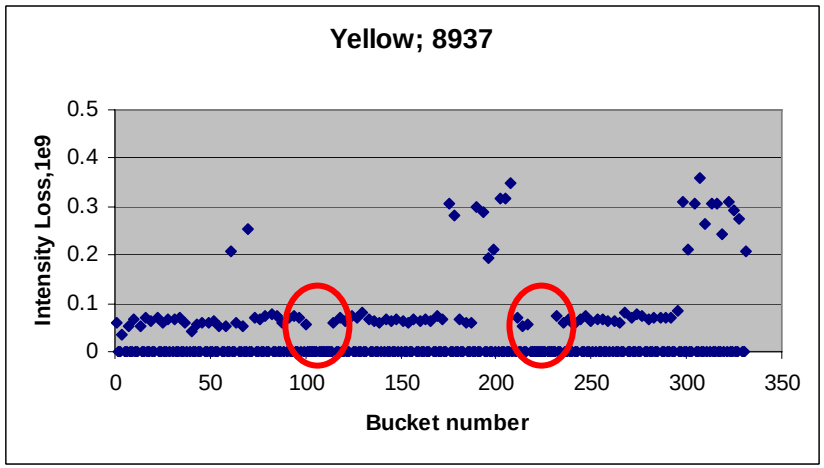


Losses along the bunch train

1o3 Std.



103 f.g.



- 103 std. ramp (1.15) shows beam blow up in all late bunches (ramp failed)
- Next 103 fg ramp with same bunch intensity (1.17) worked
- Gap pattern clearly visible in 8837
- 103 f.g. set to be default, eliminated rebucketing problem
- Clearly indicates vacuum issue!

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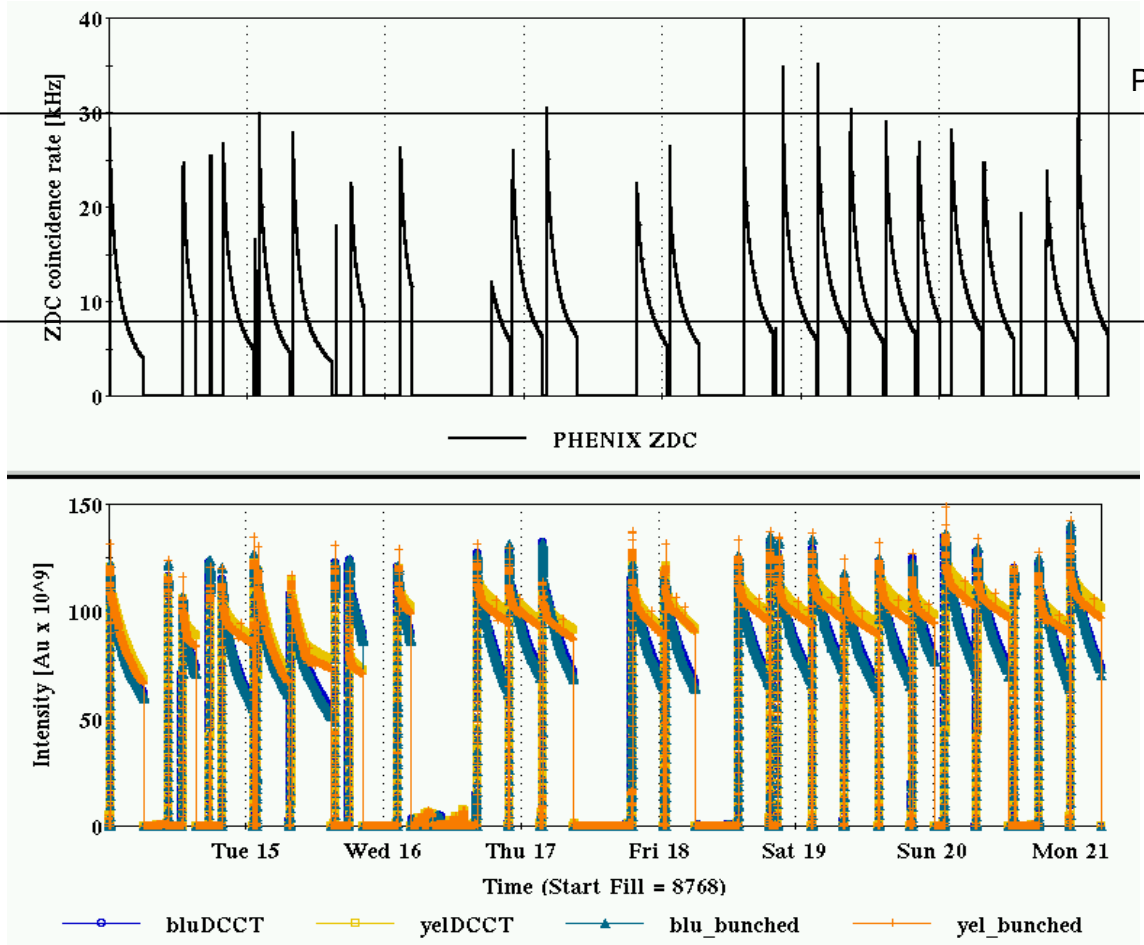
- Reach avg. luminosity/store
  - > 8 10^{26} cm-2 s-1 routinely
- Reach peak luminosity/store
  - > 30 10^{26} cm-1 s-1
- Increase bunch intensity

Example of a good week (May 14-May 20)

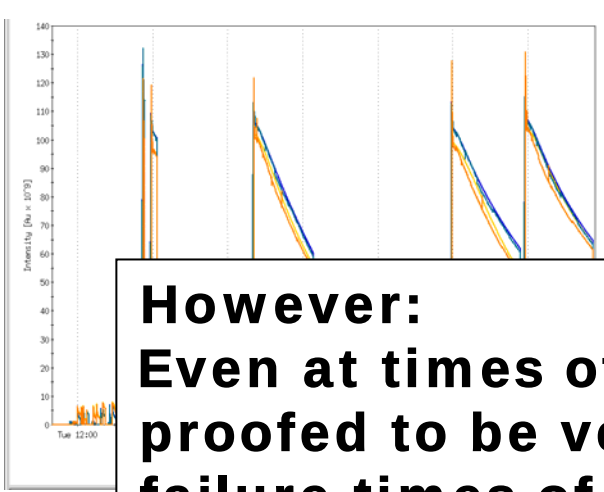


Peak luminosity of 30 10^{26} cm^{-2} s^{-1}

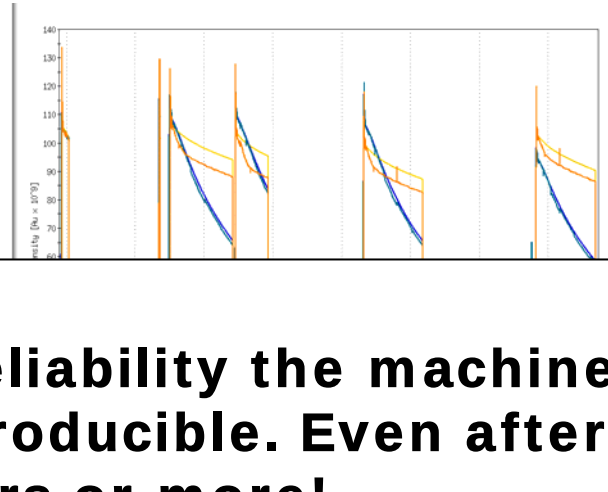
Goal avg. store luminosity of 8 10^{26} cm^{-2} s^{-1}

- This weeks integrated luminosity totaled 380 μb-1
- Stochastic cooling effect clearly visible
- Initial beam intensity routinely above 120 10^9

Example of a bad week May 28 – Jun 3

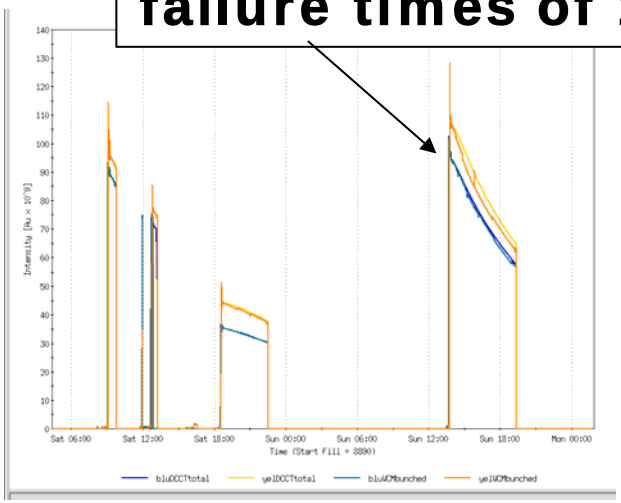


Tue-Wed

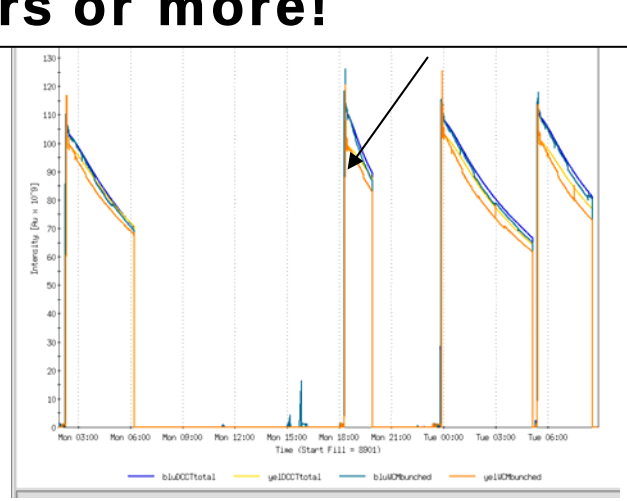


Thu-Fri

However:
Even at times of bad reliability the machine proofed to be very reproducible. Even after failure times of 18 hours or more!

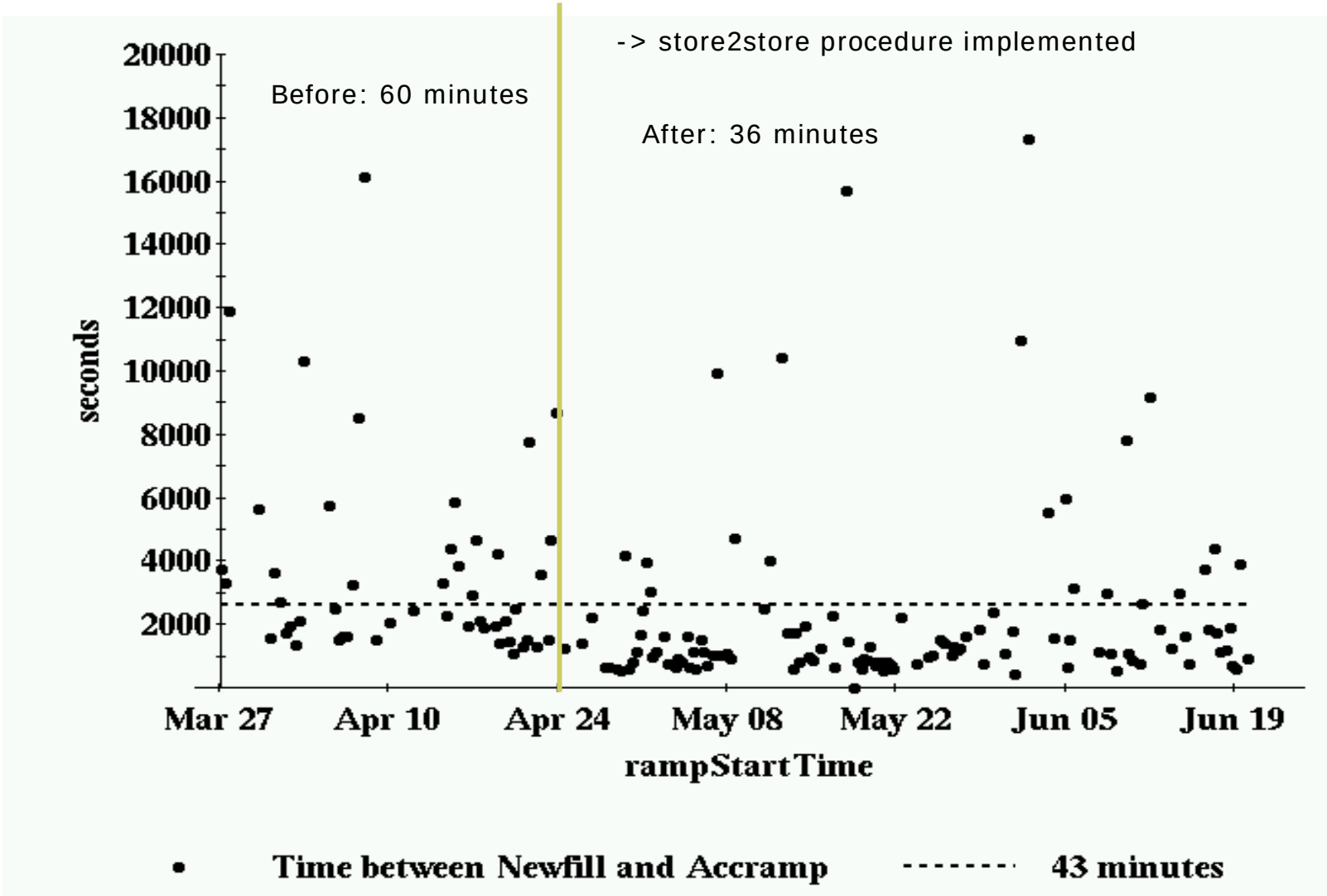


Sat-Sun



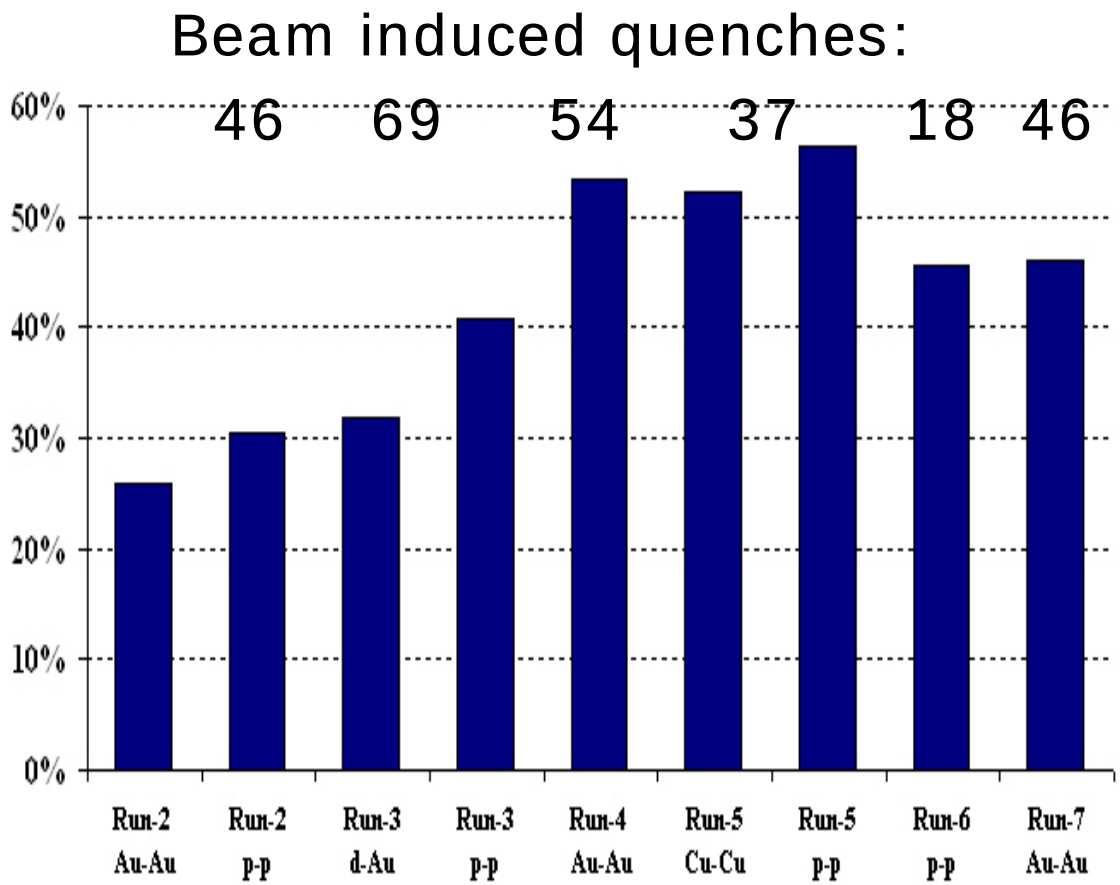
Mon-Tue

Time between newfill and accramp (turn-around indicator)



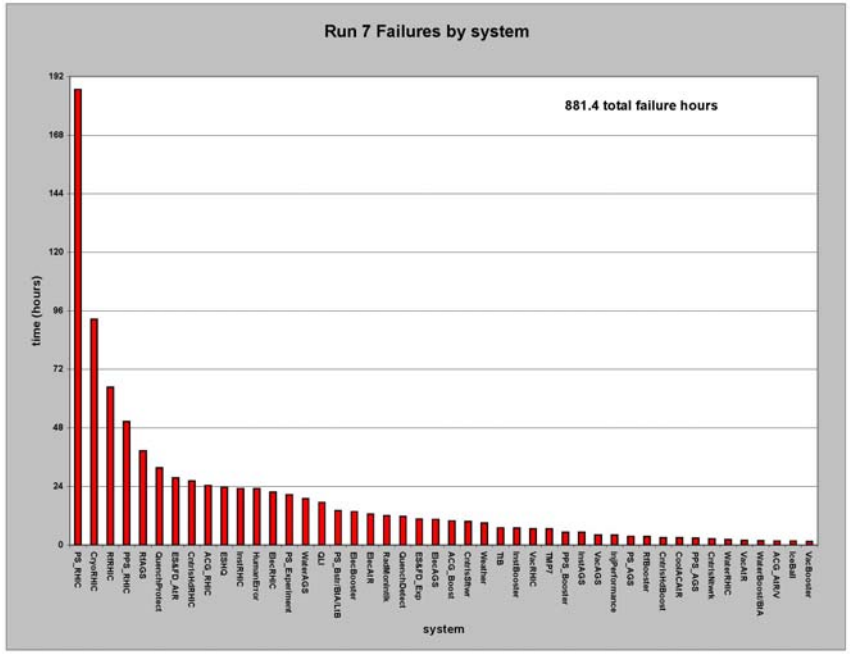
Time at store over the years

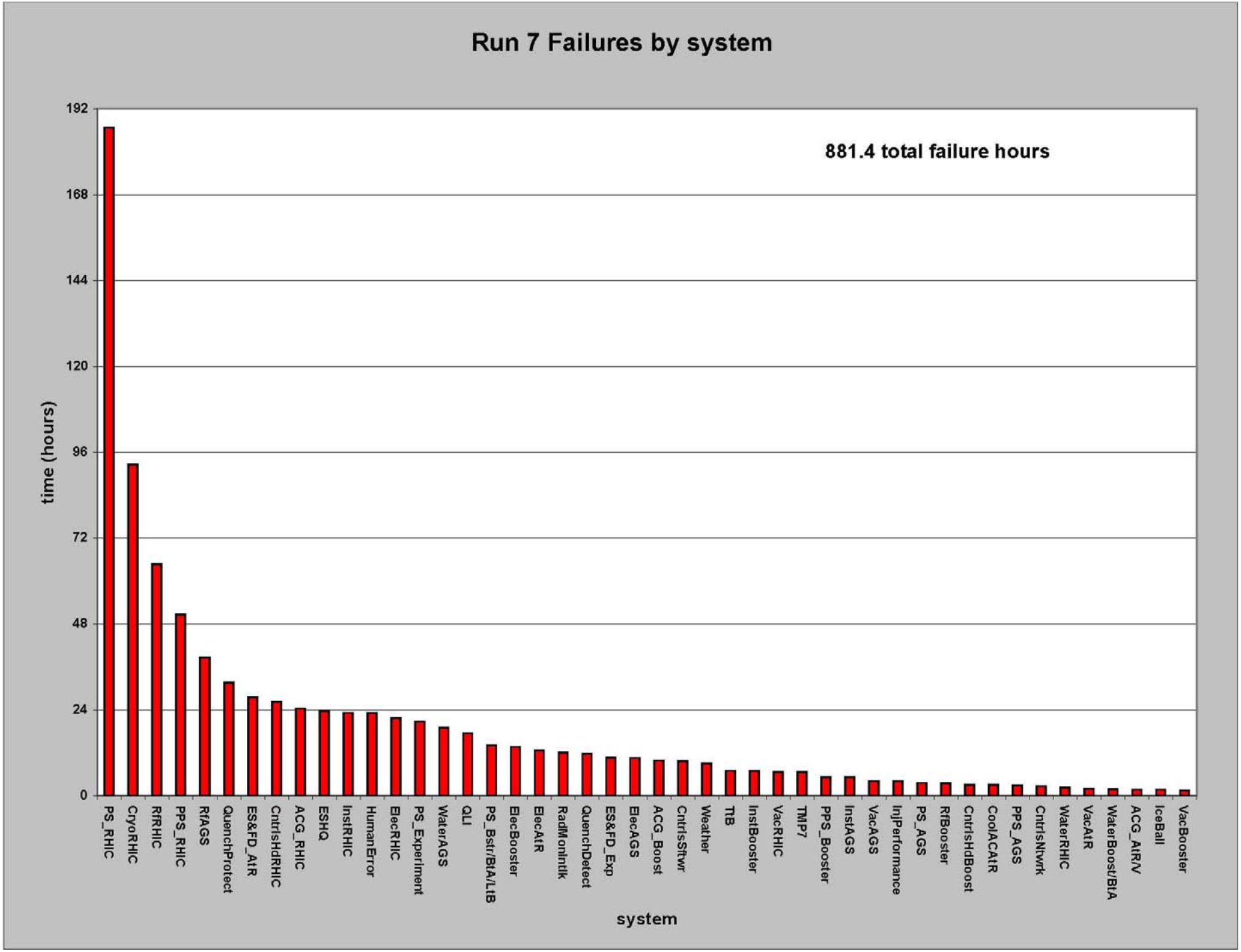
- Data included until Jun 9th 2007
- Goal: 60%
- Reached 46%
- Failed to reach goal by about 15%
- Beam induced quenches not correlated with uptime but species => magnet current



Failures in hours for Run-7 system by system

- Run-7 had
  - 13 weeks total with 3250 μb^{-1} delivered per experiment
  - Postponed start date to late spring: temperature issues
  - full magnetic field/current Au@100 GeV vs. p@100 GeV
  - Equipment aging?
  - Manpower?
- Top 3: Power supplies (PS), cryo, RHIC RF
- Increase factors (from previous run to this run)
  - PS: x2.2
  - RF: x2.5
  - Cryo: x4.5




Run 7 Failures by system
881.4 total failure hours
time (hours)
192
168
144
120
96
72
48
24
0
system
PS_RHIC
CryoRHIC
RfRHIC
PPS_RHIC
RfAGS
QuenchProtect
ES&FD_AtR
CntrlsHdRHIC
ACG_RHIC
ESHQ
InstRHIC
HumanError
ElecRHIC
PS_Experiment
WaterAGS
QLI
PS_Bstr/BtA/LtB
ElecBooster
ElecAtR
RadMonIntlk
QuenchDetect
ES&FD_Exp
ElecAGS
ACG_Boost
CntrlsSftwr
Weather
TtB
InstBooster
VacRHIC
TMP7
PPS_Booster
InstAGS
VacAGS
InjPerformance
PS_AGS
RfBooster
CntrlsHdBoost
CoolACAtR
PPS_AGS
CntrlsNtwrk
WaterRHIC
VacAtR
WaterBoost/BtA
ACG_AtR/V
IceBall
VacBooster

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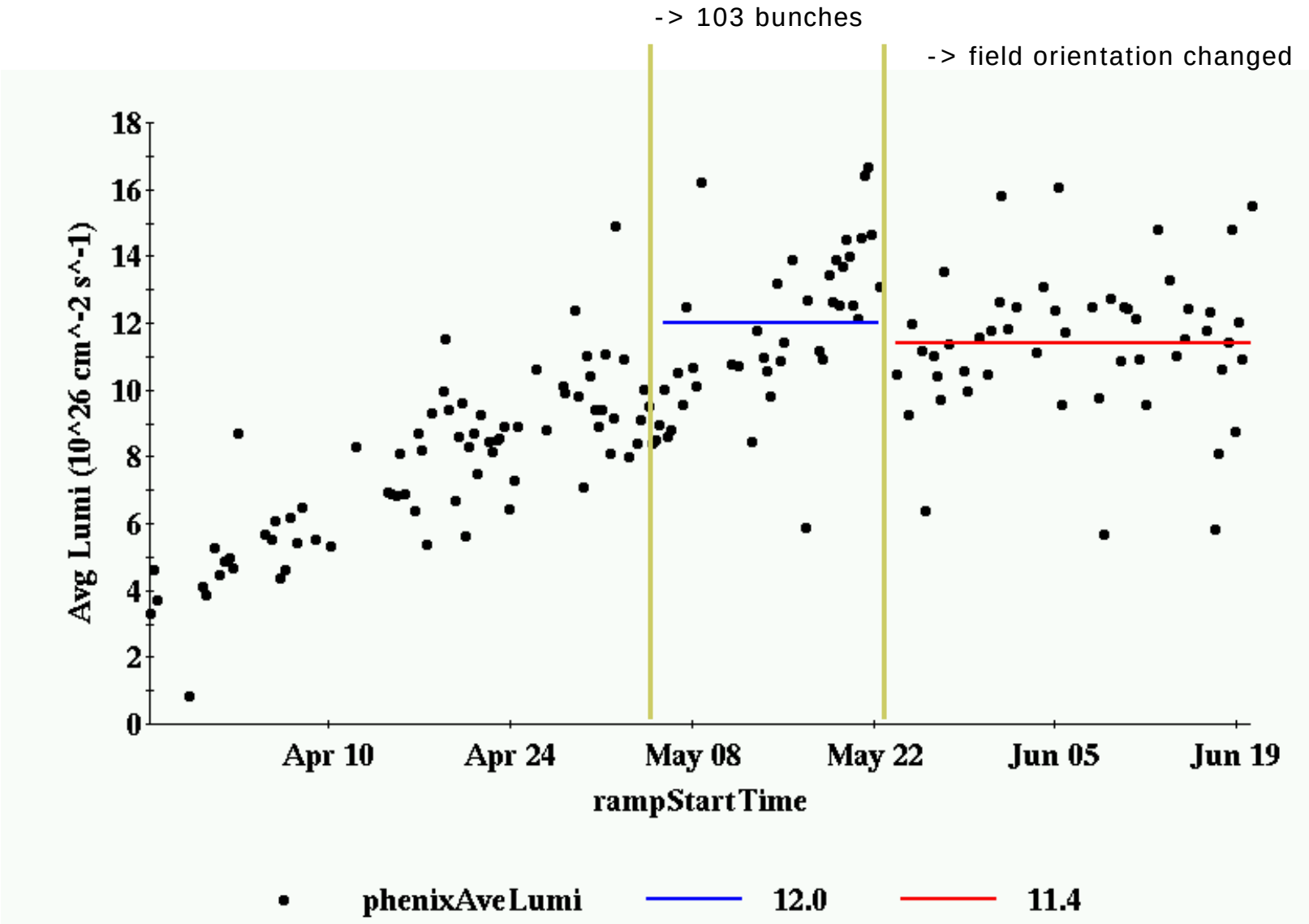
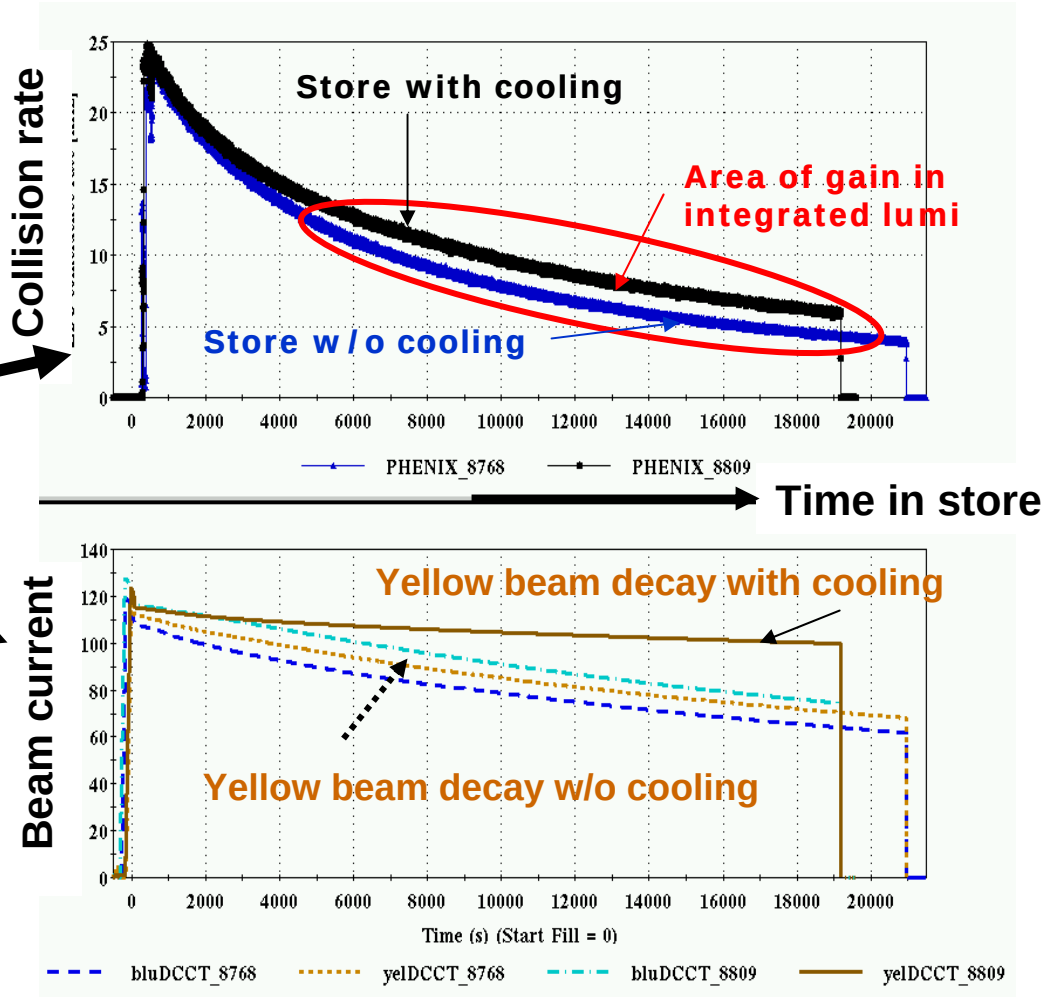
- Increase bunch intensity

Run7 average luminosity highest with 103 bunches/ring

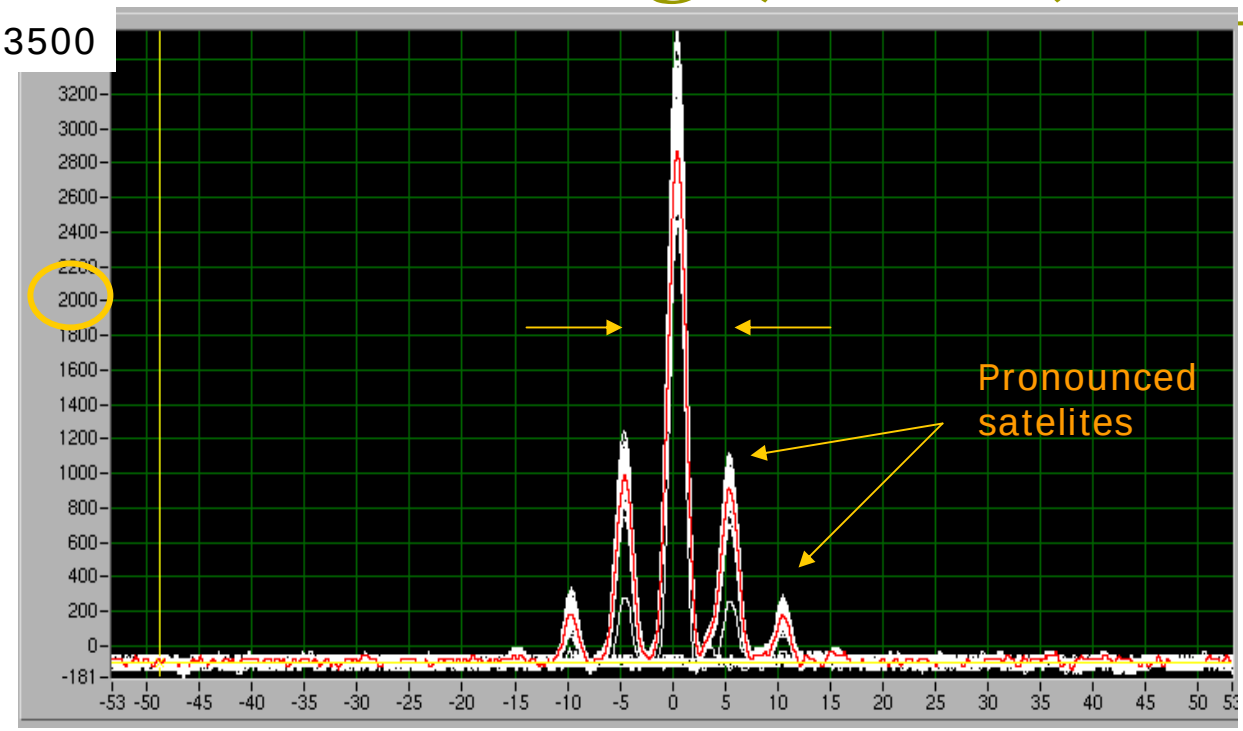


Stochastic Cooling (Yellow only)

- Stochastic (longitudinal) cooling was commissioned and made operational for the 2nd half of the run
- **Increased luminosity lifetime**
- More beam in the center bucket (next slide)
- **Yellow beam decay reduced to "burn off rate"**
- Net-effect on integrated luminosity 10%-20% (analysis not yet finished), PHENIX indicates an average 16% effect



Stochastic Cooling (contd.)



Blue beam uncooled

Yellow beam cooled

- Uncooled beam has larger width of center bucket
- Cooled beam has significantly pronounced center and satellite buckets
- Exp. recorded luminosity benefited from prolonged luminosity lifetime as well as more beam in the central bucket (vertex cut!)

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- Reach peak luminosity/store
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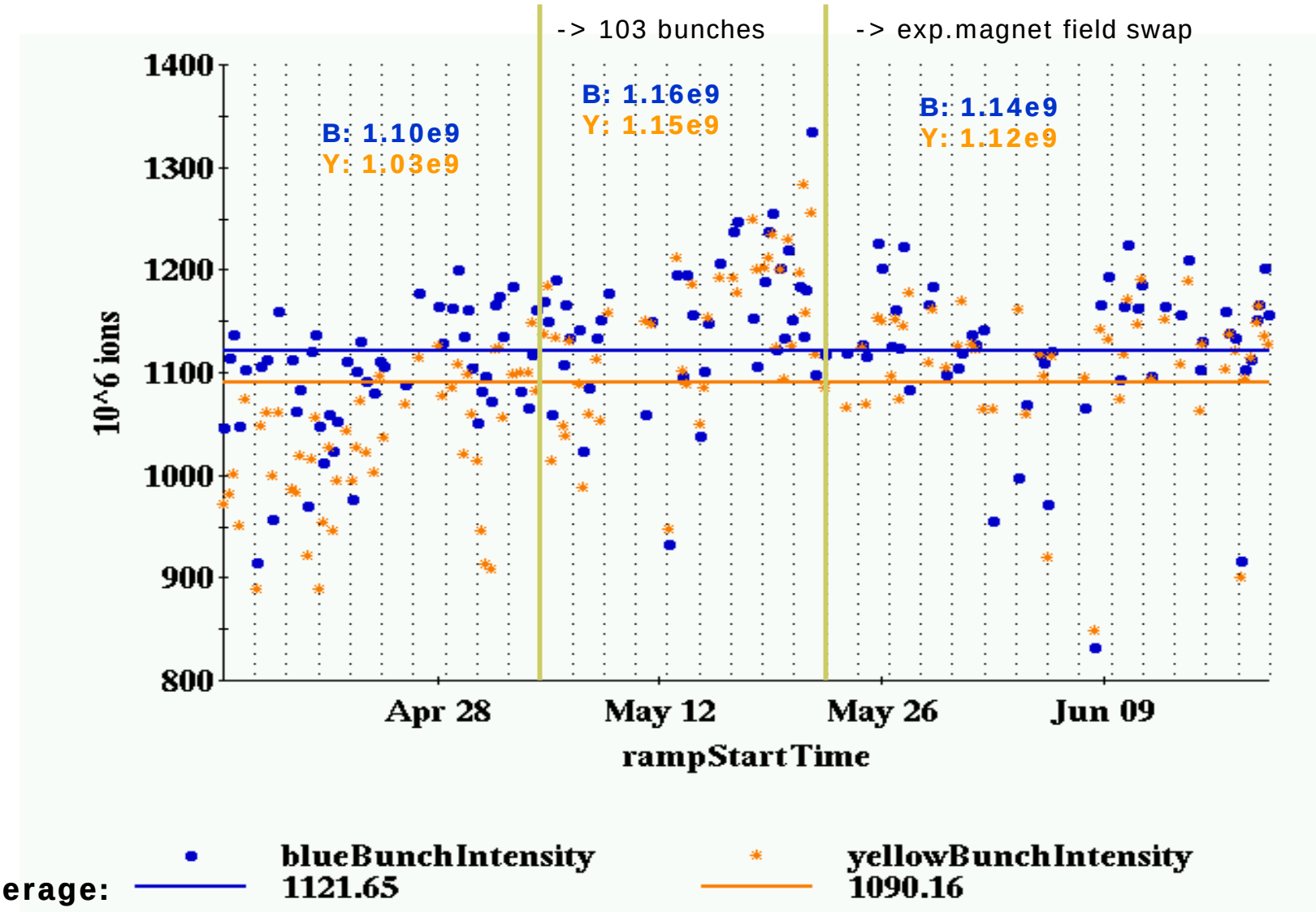
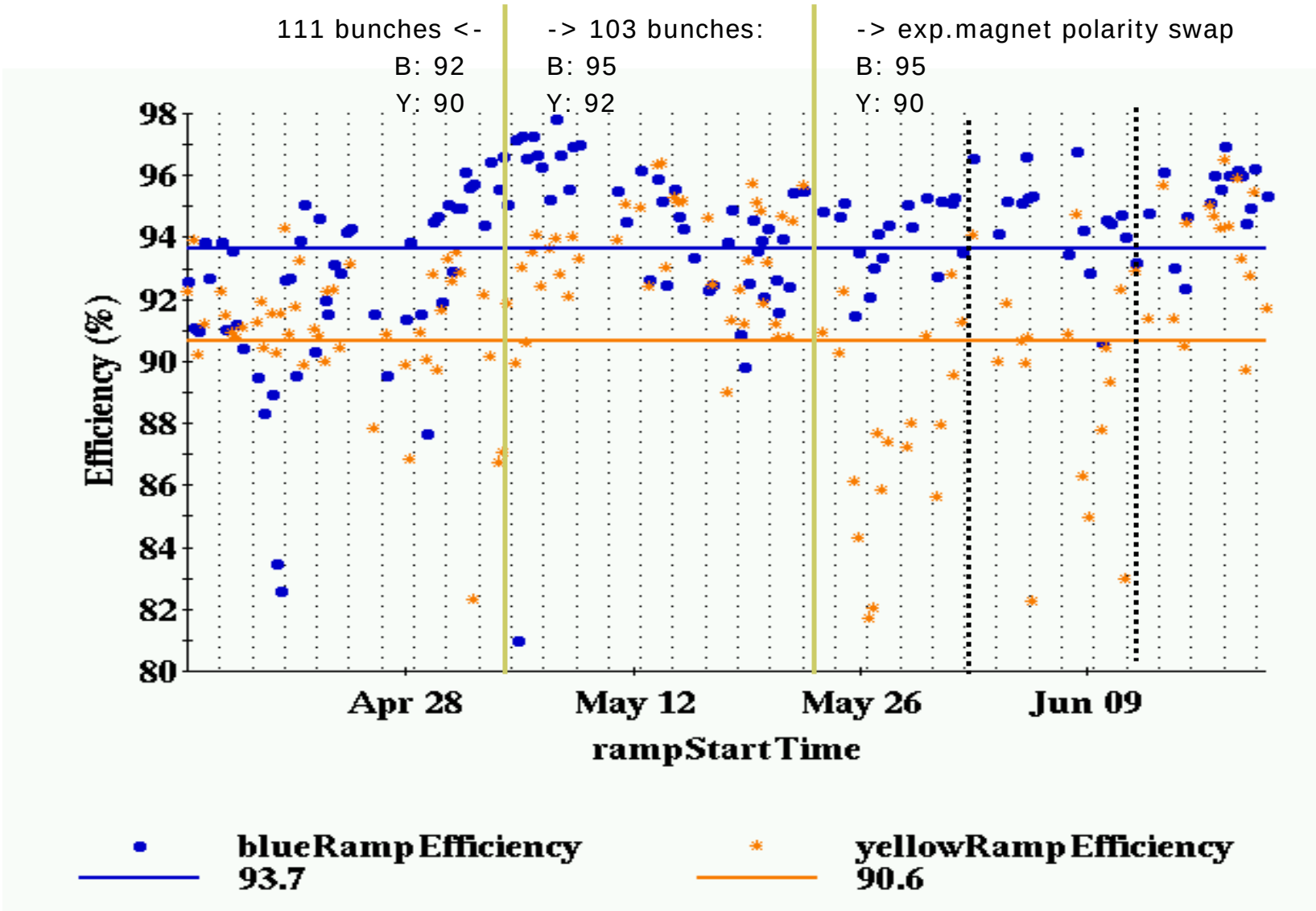
- Increase bunch intensity

Bunch Intensity at Injection

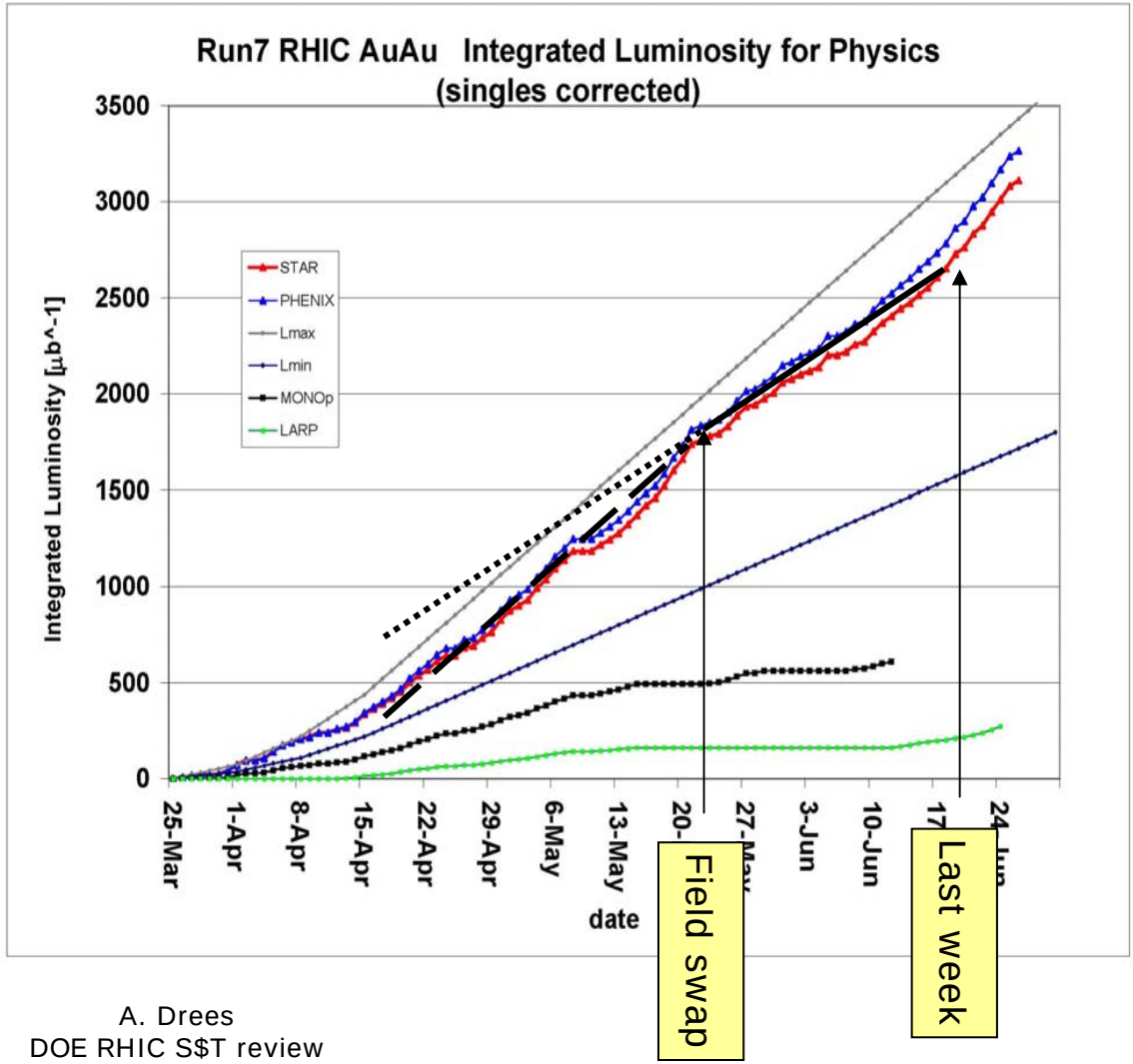


Ramp Efficiency

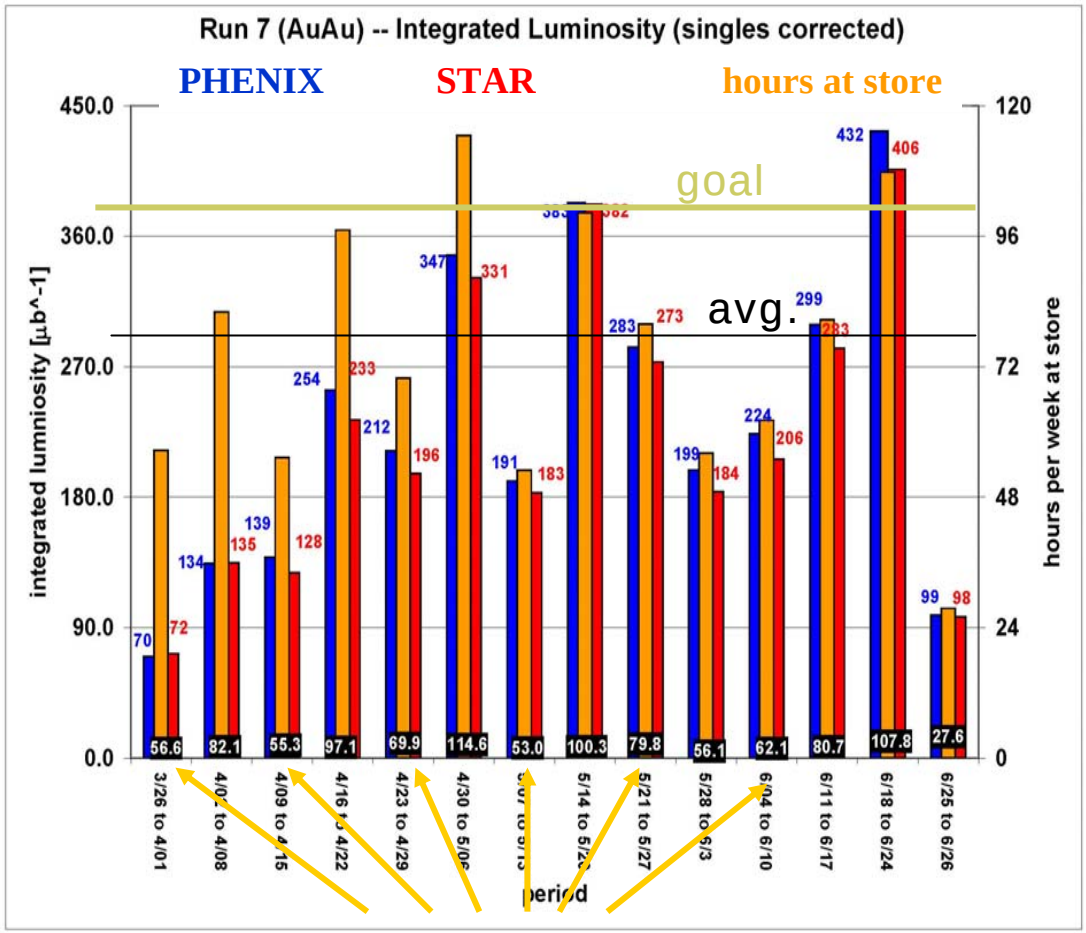


Integrated Au-Au Luminosity Run-7

- Luminosity corrected for accidental collisions (due to high collision rate)
- **Slope change after experimental magnets polarity flip**
- Last week better again (recovery? Coincidence?)
- Integrated luminosity reaches ~90% of most optimistic projection!



Week-by-week integrated luminosity Run 7



- Bi-weekly pattern in early run
- 3 weeks above 300 μb^{-1}
- Even with reduced **reliability** we delivered about 90% or our most optimisitc predictions for Run-7
- How did we do that?
  - Machine **reproducibility** was very high ☺
  - We exceeded the goal avg. luminosity/store by 50%! ☺
  - Stochastic cooling contributed more than expected ☺

Expectations and Goals for Run-7

- Do better than Run-4 ;) ☺
- Increase number of bunches to 111 ☺
- Reach 60% time at store on average no
- Reach avg. luminosity/store ☺
  - > 8 10^{26} cm-2 s-1 routinely
- Reach peak luminosity/store ☺
  - > 30 10^{26} cm-1 s-1
- Increase bunch intensity -

Conclusions

- 3250 μb^{-1}/exp. delivered in 13 weeks, 90% eff. Reached in 4 days, low energy setup in 24 h
- We met and exceeded our goals:
  - 111 (103) bunches: 2.3 x Run-4
  - Achieved > 12 10^{26} cm^{-2} s^{-1} avg. luminosity/store routinely : 2-3 x Run-4
  - > 30 10^{26} cm^{-1} s^{-1} peak luminosity, 2-2.5 x Run-4
  - Some weeks (3!) exceeded 300 ub^{-1} integrated luminosity
  - Achieved integrated luminosity: 2-3 x Run-4 (delivered vs. recorded)
- Bunch intensity limit (~1.2 10^{9}) reached
- Up-time or reliability needs significant changes:
  - Plans for next year (short shutdown!)
  - Long-term plans
- Stochastic Cooling concept worked better than expected (10-20% gain)

Conclusions

- 3250 μb^{-1}/exp. delivered in 13 weeks, 90% eff.

run	year	$\beta*$ (m)	no. of bunches	ions/bunch 10^9	$\epsilon_{x,y}^{norm.}$ (π mm mrad)	$\mathcal{L}_{peak}$ ($10^{26}cm^{-2}s^{-1}$)	$\mathcal{L}_{avg.}$	$\mathcal{L}_{week}$ (μb^{-1})
design		2	55	1.0	15-40	9	2	50
enhanced design		1	111	1.0	15-40	30	8	300
Run-2	FY2001/02	1	55	0.5	15-40	3.7	1.5	24
Run-4	FY2004	1	45	1.1	15-40	15	5	160
Run-7	**FY2007**	**0.8 (1?)**	**111**	**1.1**	**15-40**	**30**	**10-14**	**200-400**

We not only reached but exceeded our enhanced design goals as well as reaching ~ 90% of our most optimistic projections!